AD-A118 155 ARINC RESEARCH CORP ANNAPOLIS MD F/G 13/10
SYSTEM ENGINEERING ANALYSIS OF COMPRESSED AIR SYSTEMS INSTALLED--ETC(U)
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SYSTEM ENGINEERING ANALYSIS OF COMPRESSED AIR SYSTEMS INSTALLED ON LHA-1 AND LPH-2 CLASS SHIPS

July 1982

Prepared for
PLANNING AND ENGINEERING FOR REPAIRS AND ALTERATIONS
AMPHIBIOUS SHIPS AND CRAFT
PORTSMOUTH, VIRGINIA
under Contract N00189-81-D-0126-FJ07

ARINC RESEARCH CORPORATION

DISTRIBUTION STATEMENT A
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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER 2657-01-2-2753	2. GOVT ACCESSION NO. AD-A118 155	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) System engineering analysis of compressed air systems installed on LHA-1 and LPH-2 class ships.		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER 2657-01-2-2753
7. AUTHOR(s) L. H. Brown		8. CONTRACT OR GRANT NUMBER(s) N00189-81-D-0126-~~FJ07~~
9. PERFORMING ORGANIZATION NAME AND ADDRESS ARINC Research Corp. 2551 Riva Road Annapolis, Md. 21401		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Planning & Engineering for Repairs & Alterations Amphibious Ships and Craft Portsmouth, Va.		12. REPORT DATE July 1982 13. NUMBER OF PAGES 51
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Unlimited

DISTRIBUTION STATEMENT A
Approved for public release;
Distribution Unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

System Engineering
Compressed Air Systems
LHA-1 Class Ships
LPH-2 Class Ships

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The analysis documented herein is specifically applicable to the Compressed Air System--ship's work authorization boundary (SWAB) groups 5511, 5512, 5513, and 5515--installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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L. H. Brown

ARINC Research Corporation
a Subsidiary of Aeronautical Radio, Inc.
2551 Riva Road
Annapolis, Maryland 21401

Publication 2657-01-2-2753

SUMMARY

The goal of an engineered operating cycle (EOC) program is to effect an early improvement in the material condition of ships at an acceptable cost, while maintaining or increasing their operational availability during an extended operating cycle. In support of this goal, system engineering analyses (SEAs) are being conducted for various ship classes on selected mission-critical systems and subsystems that have historically exhibited relatively high maintenance burdens. This report documents the SEA for the compressed air system on LHA-1 and LPH-2 Class ships. The report was developed for PERA (ASC) under Delivery Order FJ-07 of Navy Contract N00189-81-D-0126.

The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect operational performance and maintenance programs of a ship system and the significance of these requirements to an EOC program. The report documents a recommended system maintenance strategy and specific maintenance actions best suited to meeting EOC goals.

The major findings and conclusions of the SEA for LHA-1 and LPH-2 Class compressed air systems are summarized as follows:

- An "on condition" maintenance strategy should be adopted for the compressed air systems.
- Ship's force and IMAs are capable of overhauling air compressors. Time-directed overhauls of all air compressors during regular overhaul are neither practical nor warranted.
- The compressed air systems should be repaired during regular overhaul to the extent shown to be necessary by POT&I results, MCA, and CSMP.
- Failures of the air compressors are generally random, and in most cases ship's force can complete the necessary repairs with limited outside assistance.
- The corrective maintenance history of the compressed air system did not show any failure modes or repetitive maintenance actions indicative of design-related problems.
- With only minor changes the PMS requirements for the compressed air system are adequate.

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CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

System engineering analyses (SEAs) are being conducted on selected systems and subsystems of designated ships of the Amphibious Force in support of an engineered operating cycle (EOC) program. The SEA is an analysis of the impact of historical preventive and corrective maintenance requirements that affect the operational performance and maintenance programs of a ship system. It serves as a vehicle for assessing the significance of these maintenance requirements to an EOC program. The objective of a SEA is to define and document a maintenance program that will prevent or minimize the need for unscheduled maintenance, while improving material condition and maintaining or increasing system availability throughout an engineered operating cycle.

1.2 SCOPE

The analysis documented herein is specifically applicable to the Compressed Air System -- ship's work authorization boundary (SWAB) groups 5511, 5512, 5513, and 5515 -- installed on LHA-1 and LPH-2 Class ships. The analysis considers only the systems and equipments installed and the documentation effective as of 22 April 1981. This system was selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden.

The analysis used all available documented data sources from which system maintenance requirements could be identified and studied. These included the maintenance data system (MDS), casualty reports (CASREPs), planned maintenance system (PMS) requirements, ship alteration and repair packages (SARPs), system alteration information, system technical manuals, ship corrosion-control manuals, and Engineered Operating Cycle (EOC) system maintenance analyses (SMAs) previously conducted for functionally similar systems and equipments installed on EOC program ships. Sources of undocumented data used in this analysis included discussions with ships' operating personnel and cognizant Navy technical personnel.

1.3 REPORT FORMAT

The following chapters describe the analysis approach (Chapter Two), present the significant system maintenance experience and essential maintenance requirements (Chapter Three), and summarize the conclusions and recommendations derived from the analysis (Chapter Four). Appendix A defines the system boundaries used in conducting this analysis, and Appendix B lists the specific components that constitute the Compressed Air System as installed on individual ships of the ship classes under study. Appendix C specifies the Maintenance Index Pages (MIPs) applicable to the major components of the Amphibious Class Ships' Compressed Air System. Appendix D lists all sources of information used in this analysis. Appendix E presents corrosion-control information applicable to selected equipments of the compressed air system.

CHAPTER TWO

APPROACH

2.1 OVERVIEW

This chapter describes the approach followed in performing the SEA for the Compressed Air System installed on LHA-1 and LPH-2 Class ships. The systems were selected for analysis by PERA (ASC) on the basis of its mission criticality and historical maintenance burden. Data from sources mentioned in Section 1.2 were used to identify, define, and analyze maintenance requirements that will significantly affect the system's operational availability and material condition. A recommended maintenance strategy and implementation procedures were formulated on the basis of the analysis results. The major steps of the analysis were as follows:

- Task 1: Compile data and prepare maintenance history profile
- Task 2: Analyze problems and causes
- Task 3: Analyze solutions to problems
- Task 4: Document SEA results

The following sections briefly describe each of the major tasks.

2.2 TASK 1: COMPILE DATA AND PREPARE MAINTENANCE HISTORY PROFILE

During Task 1, the configuration, boundaries, and functions of the system were defined; maintenance, engineering, and operating data were collected; and the maintenance history profile was prepared, describing the corrective maintenance historically performed. These items provided basic reference data for the remaining SEA tasks.

2.2.1 Collect Data

The analysis began with the collection of data on the historical maintenance requirements of each system. The resulting data file consisted of four key elements: an MDS data bank, a CASREP narrative summary, a current equipment configuration summary, and a summary of historical maintenance requirements. A library was also assembled from appropriate technical manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on EOC program ships.

manuals, PMS requirements, SARPs, and copies of previously completed analyses of functionally similar equipments installed on EOC program ships.

The MDS data bank was compiled by examining all MDS data reported from May 1976 through June 1981 for Hulls LHA-1 through LHA-5, and 1 January 1971 through March 1981 for Hulls LPH-2, LPH-3, LPH-7, LPH-9, LPH-10, LPH-11, and LPH-12 (a total of 12 ships).

CASREP information was obtained by reviewing the CASREPs reported on each ship's system during the period of 1 January 1976 through 22 April 1981 for LHA-1 Class ships and 1 January 1978 through 22 April 1981 for LPH-2 Class ships. CASREPs resulting from parts cannibalization of equipments by other ships were not considered.

2.2.2 Define System Configuration

Configuration information was obtained by reviewing available common configuration class lists (CCCLs), the type commander's coordinated shipboard allowance lists (COSALs), shipalt records, and MDS data. Telephone calls to specific ships and cognizant technical personnel, as necessary, confirmed system configuration.

2.2.3 Prepare Maintenance History Profile

The maintenance history profile was prepared from analysis of MDS and CASREP data and review of applicable PMS documentation and SARPs. The maintenance history profile is a working technical package describing the types of corrective and restorative maintenance historically performed on the system, the level of maintenance typically required to perform the work, an estimate of the man-hours required, and the approximate intervals at which these maintenance actions can be anticipated.

2.3 TASK 2: ANALYZE PROBLEMS AND CAUSES

In Task 2 the data summarized on the maintenance history profile forms were analyzed, together with the available engineering data, to identify maintenance, support, and design problems and their associated causes. The problems and their causes were confirmed and data related to additional problems were uncovered through discussion with ships' forces and Navy technical personnel when possible.

2.3.1 Analyze Data to Define Problems

Recurring maintenance requirements affecting the availability and material condition of the equipments constituting the system were identified by screening the maintenance history profiles developed in Task 1. Screening of the maintenance history profiles had two major objectives:

- Identification of recurring failure modes or problems that require IMA, depot, or other off-ship assistance for correction and are common to all engineering designs of the functionally similar equipments installed on the ship classes examined.

- Identification of recurring failure modes or problems that are either unique to or primarily associated with a particular equipment engineering design installed on a limited number of hulls.

Once the problems were identified, the previously completed EOC program SMAs for functionally similar equipments were reviewed to determine whether the same or similar problems had been previously identified on other ship classes. If such was the case, the need for additional detailed analysis was minimized.

2.3.2 Define Causes

Although it is presented as a separate subtask, the definition of problem causes was a continuing process that occurred concurrently with the definition of the problems. Concurrent effort was required for the following reasons:

- Problem causes were sometimes stated in the historical maintenance data.
- Causes or possible causes of problems were identified during discussions with Navy technical personnel or ships' forces.
- Problem causes had previously been identified by analysis of i- tical or functionally similar systems installed on other ship classes.

In general, the causes were grouped into three categories: maintenance strategy, design, and support.

2.3.3 Summarize Problems and Causes

The problems identified and the causes defined in Task 2 were summarized and carried forward to Task 3 for development of specific solutions. The summary descriptions included the following data:

- A statement of the problem and the most probable cause
- A summary of the pertinent maintenance history and engineering data, including man-hours, number of actions, and level of repair
- Other information affecting the problem, such as redesign work in process, applicable alterations, or the effects of maintenance availabilities

2.4 TASK 3: ANALYZE SOLUTIONS TO PROBLEMS

In Task 3 the problems identified in Task 2 were analyzed so that a recommendation could be made regarding a maintenance strategy, a support strategy, design changes for the associated equipments, or equipment that should be replaced.

2.4.1 Analyze Existing Solutions

The analysis of existing design solutions that might be applicable to the two ship classes under study had two basic objectives. The first was to determine whether the problem was known to the Navy technical community and whether or not a solution had been proposed or defined. To do so, currently authorized shipalts affecting the system or equipment under study were reviewed and, if necessary, interviews were conducted with Navy technical personnel. Where possible, the effectiveness of installed shipalts was assessed.

The second objective was to determine if the specific problem existed in other ship classes and, if it did, whether a solution had been defined and whether it was applicable to the problem associated with the ship classes under study. To meet this objective, previously completed analyses of functionally similar equipments installed on other ship classes were reviewed, and the various problems found were evaluated for similarity. If the probems were determined to be similar to those identified in this analysis, the previously developed solutions were assessed for applicability to the particular equipments installed on the ships under study. If found to be applicable, they were adopted and documented as recommendations in this report without further detailed analysis.

2.4.2 Analyze Potential Maintenance Strategies

Previously developed maintenance strategies for functionally similar equipments installed on other ship classes were reviewed for their applicability to equipment installations on the ships under study. If shown to be applicable by this analysis, they were adopted and recommended for implementation on these classes of ship.

Where previously identified maintenance strategies did not apply to the ship classes under study, maintenance strategies that could possibly apply were analyzed by using reliability-centered maintenance (RCM) logic. This approach used the information developed during previous tasks to answer a series of simple yes-no questions, which led to specific decisions concerning the suitability of scheduling maintenance tasks. Three types of maintenance tasks could result from the decision process:

- On-condition task - Inspect equipment operation to detect either experienced or impending failures
- Scheduled rework task - Rework an item before an established maximum age or operating interval is exceeded
- Scheduled discard task - Discard an item before an established maximum age or operating interval is exceeded

The results of this process led to the development of the maintenance strategies recommended for the systems and equipments under study for which previously developed maintenance strategies were inadequate.

2.4.3 Analyze Potential Solutions to Integrated Logistics Support (ILS) Problems

Analysis of possible improvements to the ILS of the systems and equipments under study was limited to only those systems or equipments having maintenance history profiles that indicated the presence of such problems. Such problems are typically identified during review of MDS or CASREP data. Excessive downtime awaiting parts and the lack of authorized on-board spares as reported in CASREPs indicated the existence of ILS problems. MDS narratives were also used to identify ILS problems, since the deferral codes frequently indicated that a particular maintenance action was deferred for lack of spare parts, technical documentation, or training or experience on the equipment. Where ILS problems were identified, previously completed analyses of functionally similar systems or equipments were reviewed to determine if similar ILS problems had been identified. If they had, and if satisfactory solutions had been defined and recommended, those solutions were adopted and documented as recommendations in this report without further detailed analysis. Otherwise, further analysis was conducted to define an appropriate solution.

Each ILS problem was assessed in terms of its significance and the feasibility of successfully implementing a cost-effective solution. Only those solutions judged to be essential and cost-effective were recommended.

2.4.4 Select Effective Solutions

An effective solution was selected by the analyst on the basis of its merit or essentiality with respect to its projected cost and risk. All candidate solutions, whether resulting from this analysis or from previously conducted analyses of functionally similar equipments, that were judged to improve personnel safety or primary mission reliability were assessed on the basis of projected cost and feasibility. If these candidate solutions were not clearly feasible, or if their value, in terms of reduced maintenance burden or improved equipment reliability, was not significant, they were not recommended for implementation.

2.5 TASK 4: DOCUMENT SEA RESULTS

The Task 4 approach was to present the analysis results in a concise, logical format that included an introduction to the SEA objectives, a summary of the technical approach used, a presentation of the analysis results, and a section listing the specific conclusions and recommendations resulting from the analysis. Appendixes were included as necessary to show pertinent data affecting the system, including a table defining the configurations by allowance parts list (APL) number for each LHA-1 and LPH-2 Class hull included in the analysis.

CHAPTER THREE

RESULTS

3.1 SYSTEM DESCRIPTION AND CRITICALITY

3.1.1 Description

The compressed air systems discussed in this report are composed of various equipments included within SWAB groups 551-1, 551-2, 551-3, and 551-5. All of the major equipments (listed in Appendix A) were examined to identify maintenance requirements. The major components examined and discussed in this report include the high-pressure, medium-pressure, and low-pressure air compressors.

The LHA-1 Class ships use two complete compressed air systems: one medium-pressure and one low-pressure. The LPH-2 Class ships also use two complete compressed air systems: one high-pressure and one low-pressure.

The medium-pressure air system on the LHA-1 Class provides air for starting the emergency diesel generators, for ejecting gas from the 5"/54 gun mount, and for emergency back-up of the propulsion controls and medical services, all through a cross-connection and pressure-reducing system. The low-pressure air system on the LHA-1 Class provides compressed air for general shipboard service, propulsion controls, medical system, deballast controls, radar waveguides, air conditioning chiller controls, electronic cooling temperature controls, cargo handling, and lube oil pressure controls. The system also includes a special accumulator for the cargo-handling air and a dehydrator for the radar waveguide air.

The high-pressure air system on the LPH-2 Class provides air for starting the emergency diesel generators and for operation of the aircraft elevators, cargo elevator hatches, and the calibration laboratory. The low-pressure air system on the LPH-2 Class provides compressed air for general shipboard service, propulsion controls, medical system, deballast controls, radar waveguides, air conditioning chiller controls, electronic cooling temperature controls, cargo handling, and lube oil pressure controls.

3.1.2 Criticality

Each compressed air system is served by its own air compressors. High-pressure (HP) medium-pressure (MP), and low-pressure (LP) air compressors (AC) are included in SWAB group 551-5. In terms of maintenance burden, the prioritized critical-equipments lists for the LHA-1 and LPH-2 Classes rank the compressed air system number 7 of 118 (top 6 percent) and number 9 of 88 (top 10 percent), respectively, of the major ship systems. An indication of the criticality that can be attributed to an air compressor failure is the degree to which the installed compressors are redundant. Table 3-1 summarizes the redundancy of installed air compressors for the LHA-1 and LPH-2 Class ships. From this table it is evident that considerable redundancy has been designed into the compressed air systems.

3.2 SYSTEM MAINTENANCE HISTORY OVERVIEW

3.2.1 MDS Summary

Maintenance data were initially screened to identify the possible existence of significant maintenance-related problems unique to a particular engineering design, as discussed in Section 2.3. Maintenance burden data for the compressed air system are summarized in Table 3-2. All corrective maintenance on the air compressor components was reported against the compressor APLs: the lube oil system, cooling system, bearings, shaft, shaft seals, pistons, piston rings, cylinders, cylinder liners, bushings, lubricators, suction and discharge valve assemblies, unloader assemblies, and other internal parts.

Only 15 significant intermediate maintenance activity (IMA) and ship's force maintenance-related transactions were reported for the combined medium-pressure and low-pressure compressed air systems installed in LHA-1 Class ships during the MDS data period. These were judged to represent an insufficient quantity of data upon which to base an analysis inasmuch as the average age of LHA-1 Class ships is only 3.5 years while that for LPH-2 Class ships is 17.5 years. It is therefore recommended that the general maintenance strategies developed in this report for the LPH-2 Class ships be adopted for the LHA-1 Class ships until sufficient maintenance data are available to permit evaluating the appropriateness of the current maintenance strategy for LHA-1 Class ships.

A review of the MDS data showed that the seven ships of the LPH-2 Class reported a total of 84 JCNs for the air compressors. A total of 12,755 maintenance man-hours (1,706 ship's force and 11,049 IMA) and $236,891 in part-replacement costs were reported by all the ships reviewed (see Table 3-2). The figures shown in Table 3-2 include the maintenance burden for the high-pressure and low-pressure air compressors. Forty-eight JCNs for the high-pressure air compressors and 35 JCNs for the low-pressure air compressors were reported. The seven ships reported 5,188 significant ship's force and intermediate maintenance activity maintenance-related man-hours (1,278 ship's force and 3,910 IMA) and $135,192 in part-replacement costs for the high-pressure air compressors, and 7,567 maintenance man-hours (428 ship's force

Table 3-1. INSTALLATION REDUNDANCY OF AIR COMPRESSORS

Ship Class	HP Air Compressor				MP Air Compressor				LP Air Compressor			
	Number Installed	Number Required		Redundant Units	Number Installed	Number Required		Redundant Units	Number Installed	Number Required		Redundant Units
		In Port	Under Way			In Port	Under Way			In Port	Under Way	
LPH-2	2	1	1	1					5*	2	3	2
LHA-1					2	1	1	1	5	2	3	2

*LPH-2 and LPH-11 Currently have four oil-lubricated LP air compressors; however, Shipalt LPH-2-571D replaces the four air compressors with five oil-free LP air compressors. These are programmed for installation during the next ROH.

Table 3-2. SUMMARY OF MDS DATA FOR COMPRESSED AIR SYSTEMS ON LPH-2 CLASS SHIPS

APL	Nomenclature	Applicable Ships	Equipments per Ship	Total Equipment Population	Total Ship Operating Years	Ships Reported	JCNs	Man-Hours			Parts Cost Dollars	Average Man-Hours per Equipment per Operating Year*
								Ship's Force	IMA	Total		
High Pressure												
061430022	Compressor Air HIP 30CFH 3000 PSI CL A	LPH-9	2	2	7.28	1	12	652	957	1,609	6,499	110.51
061430100	Compressor Air HIP 30CFH 3000 PSI CL A	LPH-3, -7	1	2	15.54	2	6	38	1,054	1,092	41,276	70.27
061900145	Compressor Air HIP 20CFH 3000 PSI CL A	LPH-2, -7	LPH-2(2) LPH-7(1)	3	16.52	2	11	300	851	1,151	44,927	46.45
061900170	Compressor Air HIP 20CFH 3000 PSI CL A	LPH-3	1	1	7.13	1	2	129	69	198	855	111.92
061900182	Compressor Air HIP 20CFH 3000 PSI CL A	LPH-10	2	2	7.10	1	4	18	397	415	2,484	29.23
061900224	Compressor Air HIP 20CFH 3000 PSI CL B	LPH-11, -12	2	4	15.10	2	13	141	582	723	29,151	23.94
						Subtotal	48	1,278	3,910	5,188	135,192	
Low Pressure												
061900194	Compressor Air LP 100CFM 150 PSI CL S	LPH-2, -10, -11, -12	LPH-2, -10, -12(3), LPH-11(1)	10	30.31	4	29	299	6,686	5,985	76,843	78.98
061900206	Compressor Air LP 250CFM 200 PSI CL S	LPH-2	1	1	8.11	1	3	126	887	1,013	7,077	124.91
061900342	Compressor Air LP 100CFM 125 PSI	LPH-9	3	3	7.28	1	1	3	140	143	8,576	6.55
061900359	Compressor Air LP 100CFM 125 PSI CL S	LPH-3, -9	5	10	14.41	1	2	0	426	426	9,203	5.92
						Subtotal	35	428	7,139	7,567	101,699	
						Total	83	1,706	11,049	12,755	236,891	

$* \ \frac{\text{Total Man-Hours}}{\text{Total Equipment Population}} \div \frac{\text{Total Ship Operating Years}}{\text{Applicable Ships}}$

and 7,139 IMA) and $101,699 in part-replacement costs for the low-pressure air compressors. Dividing the total man-hours for the high-pressure and low-pressure air compressors (12,755) and the total parts cost ($233,891) by the total ship operating time (53.13 years) covered by the data period produces an average reported burden of approximately 240 man-hours and $4,402 in repair parts expenditures per ship per operating year. For the high-pressure air compressor, dividing the total man-hours (5,188) and the total parts cost ($135,192) by the total ship operating time (53.13 years) produces an average reported burden of approximately 98 man-hours and $2,545 in repair parts expenditures. For the low-pressure air compressors, dividing the total man-hours (7,567) and the total parts cost ($101,699) by the total ship operating time (53.13 years) produces an average burden of approximately 142 man-hours and $1,914 in repair parts per ship per operating year.

Table 3-3 summarizes the major repairs to the low-pressure and high-pressure air compressors that required major disassembly to effect the necessary repairs. Compressor components such as the lube oil system, cooling system, bearings, shaft, shaft seals, pistons, piston rings, cylinders, cylinder liners, bushings, lubricators, suction and discharge valve assemblies, and unloader assemblies are included in these repairs. The average man-hours per ship per operating year for the high-pressure air compressor (40.6) and for the low-pressure air compressor (39.4) reflect a relatively high maintenance burden for both ship's force and the IMA in comparison with other system components.

3.2.2 Depot Maintenance History

Seven LPH-2 and five LHA-1 Class SARPs were reviewed to determine the historical incidence of class B overhauls of air compressors during ROHs. The results of that review are summarized in Table 3-4. It was determined that for the LPH-2 Class the ratio of high-pressure air compressor overhauls to overhaul opportunities presented was 0.65 (9 overhauls in 14 opportunities). For the LPH-2 Class low-pressure compressors the ratio was 0.73 (24 overhauls in 33 opportunities).

The same calculations were made for the LHA-1 Class; they resulted in a ratio of 0.10 for class B overhauls of the medium-pressure (MP) compressors and 0.70 for class C repairs. The calculated ratio for class B overhauls of the LHA-1 Class low-pressure air compressor was 0.60. Since the LHA-1 Class as a whole is much newer than the LPH-2 Class, the ratio of MP air compressor overhauls to opportunities presented (0.10) can be misleading; it will probably increase with additional operating time.

Review of the maintenance experience for individual hulls, as reported through the MDS and CASREPs, indicates that ships receiving class B air compressor overhauls during ROH reported no fewer post-overhaul failures than ships receiving class C compressor repairs only. From this it is concluded that performing class B compressor overhauls during ROH does not necessarily lead to improved reliability during the subsequent operating cycle, tending to support the operating personnel's observation that recent

Table 3-3. MAINTENANCE BURDEN SUMMARY OF MAJOR REPAIRS TO AIR COMPRESSORS INSTALLED ON LPH-2 CLASS SHIPS

Nomenclature	JCNs	Ship's Force Man-Hours	IMA Man-Hours	Total Man-Hours	Average Man-Hours per JCN	Average Man-Hours per Ship per Operating Year
HPAC Major Repairs	14	919	3,397	4,316	308	40.6
LPAC Major Repairs	24	376	7,995	8,371	349	39.4

Table 3-4. DEPOT MAINTENANCE HISTORY (SARP)							
Hull Number	Class B Overhauls	Class C Repairs	Number Receiving Class B/C Overhaul				ROH Completion Dates
			H/MPAC	Percentage	LPAC	Percentage	
LPH-2	X		0	0	4	100	1/29/78
LPH-3	X		1	50	4	80	3/7/78
LPH-7	X		2	100	4	80	11/5/79
LPH-9	X		1	50	2	40	9/4/80
LPH-10	X		1	50	4	80	12/31/80
LPH-11	X		2	100	3	75	12/10/76
LPH-12	X		2	100	3	60	11/18/76
LHA-1		X	2	100	3	60	FY 78 RAV
LHA-2		X	2	100	3	60	6/13/83 (COH)
LHA-1		X	2	100	3	60	8/6/82 (COH)
LHA-3	X		1	50	4	80	1/19/82 (SRA)
LHA-2		X	0	0	2	40	7/3/81 (SRA)

air compressor class B overhauls have not been of the expected quality. The significant failure modes observed during the course of this analysis occured randomly throughout the data period and did not appear to be a function of whether or not the particular equipment had received a class B overhaul or class C repairs during the previous ROH. It was thus concluded that the routine scheduling of air compressor class B overhauls during ROH is unwarranted. The determination of maintenance requirements for particular air compressors should be based on inspection results and operational history rather than on an arbitrary time-based overhaul schedule.

3.2.3 CASREP Summary

CASREP analysis supported the MDS screening performed in defining significant maintenance actions. Table 3-5 summarizes the CASREPs submitted on the components of the compressed air system. Eleven of twelve ships examined reported a total of 42 CASREPs (35 C-2 and 7 C-3). One ship, the LPH-12, did not report any CASREPs on the compressed air system during the data period. The downtime due to various compressor internal part failures, normal wear and tear, and rupture of salt water cooler tubes accounts for most of the reported maintenance downtime. Ruptures of the salt water cooler tubes appeared to be a significant problem of both classes of ships, particularly the TARAWA, LHA-1, on which four C-2 CASREPS were

Table 3-5. COMPRESSED AIR SYSTEM CASREP SUMMARY

Reason for CASREP	LHA-1 Class					LPH-2 Class							CASREP Downtime Man-Hours		
	1	2	3	4	5	2	3	7	9	10	11	12	Due to Supply	Due to Maintenance	Totals
L.P./M.P. Air System															
Compresser/Motor															
° Oil/water leaks	3												0	2,375	2,375
° Blown piston rings/damaged piston	1	2				1							720	264	984
° Butterfly valve failed		2											0	853	853
° Dehydrator valve failed		2											0	840	840
° Cylinder scored/head warped/damaged con rod			1		1								4,401	61	4,462
° Normal wear and tear	1			1									0	319	319
° Salt water cooler tube ruptured	4						1				1		0	14,200	14,200
° Motor shorted/grounded		2											0	783	783
° Motor bearings worn	1												0	95	95
° Starter motor contactor excessive wear			1										0	0	0
° Filters (ship service diesel station recharging)	1												0	83	83
° 1500 ship's service diesel station loss air charge	1												0	482	482
° Worn internal components	2						1						0	738	738
° Water pump inoperative									1				0	4,136	4,136
° Overheating									1				1,500	385	1,885
° Air dryer cycle timer malfunction										2			32	545	577
° Cylinder liner scored/oil and compression rings worn/faulty unloaders											1		0	1,508	1,508
Subtotals	14	8	2	1	1	1	2	0	2	2	2	0	6,653	27,667	34,320
H.P. Air System (LPH-2 Class Only)															
Compresser/Motor															
° Lube oil cooler walt water leak						1							912	472	1,384
° Fourth stage suction/discharge valve worn beyond repair						1							792	175	967
° Normal wear and tear						1							0	2,120	2,120
° Motor shorted							1						0	94	94
° Seal rings, cylinder liners and 3rd stage tubing scored							1						0	2,170	2,170
° Crankshaft scored, con rod bearings wiped, wrist pins scored								1					144	101	245
° Cooling water gage malfunction										1			0	0	0
Subtotals	0	0	0	0	0	3	2	1	0	1	0	0	1,848	5,132	6,980
TOTALS	14	8	2	1	1	4	4	1	2	3	2	0	8,501	32,799	41,300

Note: CASREPs - LHA-1 Class C2-20, C3-5
LPH-2 Class C2-15, C3-2
No CASREPs were reported by LPH-12.

reported. Of the total downtime reported for both classes of ships, 14,200 hours were for salt water cooler tube leaks, representing 34 percent of the total downtime burden for all CASREPs reported. Cylinder liners, seal rings, third-stage tubing, lube oil salt water cooler, and normal wear and tear (compressor internal parts) failures accounted for 5,674 hours of downtime for the LPH-2 Class. This represents 81 percent of the IWO JIMA Class downtime burden for the high-pressure air compressors. Only 16 of the 42 CASREPs (38 percent) reported were submitted by IWO JIMA Class ships. The largest number of CASREPs reported by the LHA-1 Class ships, 22 (77 percent), were submitted by the TARAWA and the SAIPAN -- 14 and 18, respectively. These two ships were undergoing post-shakedown availabilities after commissioning during the period in which these CASREPs occurred. The remaining CASREP data indicate that the other casualties occurred randomly and were not repetitive. Ship's force personnel stated that, except for those instances in which spare parts were unavailable, they were capable of making the necessary repairs to restore casualties with only occasional assistance from the IMAs.

The CASREP analysis showed that the low-pressure air compressor downtime attributed to the unavailability of spare parts in the supply system totaled 6,663 hours: 4,401 hours for cylinder scores, warped heads, and damaged connecting rods; 720 hours for blown piston rings and damaged pistons; 1,500 hours for compressor overheating; and 32 hours for air dryer cycle-timer malfunctions. The high-pressure air compressor CASREP analysis showed a total downtime of 1,848 hours for unavailability of spare parts in the supply system: 912 for lube oil cooler salt water leaks; 792 for worn fourth-stage suction and discharge valves; and 144 for wiped connecting rod bearings, scored wrist pins, and crankshafts. The HPAC and LPAC downtime attributed to the unavailability of compressor internal parts in the supply system was cited as a significant problem by ship's force technical personnel on board all ships visited. The LHA-1 Class ships reported 20 C-2 CASREPs and 5 C-3 CASREPs. The LPH-2 Class ships reported 15 C-2 CASREPs and 2 C-3 CASREPs. These severity codes indicate that the majority of failures were not considered to affect the ships' mission significantly.

3.2.4 Current Maintenance Policy

The current maintenance policy for the compressed air system is based primarily on two major sources: the PMS and the type commanders' maintenance manuals. The PMS details the day-to-day maintenance to be performed by ship's force. COMNAVSURFLANT and COMNAVSURFPAC maintenance manuals define a general maintenance policy for compressed air systems and specify air compressor inspection requirements. The maintenance policy is to perform PMS tests and checks, either on schedule or on condition, in combination with the type commander compressed air system tests and inspections. Before regular overhaul, the compressed air system is inspected to identify the repairs that are necessary to ensure reliable operation during deployments and intracycle periods. Both the PMS and type commander requirements are discussed in more detail in the following sections.

3.2.5 PMS

A number of maintenance index pages (MIPs) are specified for the individual components of the compressed air system (see Appendix C for a list of the specific MIPs applicable to this system). The latest update of the compressed air system MIPs reflects increased reliance on on-condition or "situational requirement" maintenance actions -- that is, maintenance that is accomplished only when some specified condition or performance limit (e.g., compressor operating hours or compression pressure) is reached. Some maintenance requirements are to be performed either on schedule or on condition. An examination of the PMS requirements determined that they are comprehensive and practical and, in combination with the COMNAVSURFLANTINST and COMNAVSURFPACINST inspection requirements, should be adequate to maintain the system. PMS requirements for the compressed air system (LPAC, MPAC, HPAC) that require Industrial Activity assistance are as follows:

- Remove, clean, inspect, test, and preserve air flask/accumulators every six years. The man-day estimate, based on available SARPs reviewed, indicates that approximately 31 man-days are required for this task.
- Repair, clean, inspect, test, and preserve separator flasks every three years. The man-day estimate, based on available SARPs reviewed, indicates that approximately 20 man-days are required for this task.

3.2.6 TYCOM Maintenance Manuals

COMNAVSURFLANTINST 9000.1 and COMNAVSURFPACINST 4700.1 define a general maintenance strategy for compressed air systems and specify air compressor inspection requirements. The strategy specified in those documents reflects the PMS emphasis on an on-condition strategy. Both documents emphasize graphic displays of trends derived from operating log readings to depict the condition of an air compressor, since trends of the operating parameters can be excellent indicators of air compressor condition.

Both manuals specify that the compressed air systems are to be inspected at certain prescribed times and are to be subjected to spectrometric lube oil analysis, which is an analysis of the chemical composition of the lube oil; and physical lube oil analysis, which is a determination of the change in physical properties of the lube oil over time. The Navy has established the Navy Oil Analysis Program (NOAP) to conduct physical and spectrometric tests of lube oil from many different shipboard equipments (including air compressors), record and trend the results of those tests, and identify potential failures and prevent them whenever possible. The NOAP works in conjunction with PMS, inasmuch as ship's force is required to obtain lube oil samples from compressors and submit them each quarter. NOAP personnel said that there has been good correlation between test results and identification (and prevention) of failures across all types of equipments that are part of the NOAP. The program is successful and is a major element of the maintenance strategy for the compressed air system.

3.2.7 Corrosion

The data for the LHA-1 and LPH-2 Class ships were reviewed for any indication of corrosion problems in the compressed air systems. Past analyses on other ship classes have shown that corrosion is a significant problem in pump rooms and machinery rooms, especially in the wet areas of those rooms. Corrosion is caused by several factors: a large number of equipments confined in a small area, poor ventilation with resulting condensation, direct reaction of metal surfaces with oxygen in the air, and steam and salt water leakage. Ship visits and the available data revealed that corrosion of the compressed air system on the LHA-1 and LPH-2 Class ships was not yet a significant problem. Ship's force personnel expressed the opinion that routine maintenance and preservation of the equipment should limit the spread of corrosion.

Although there were no signs of excessive corrosion, it appeard that compressor foundations, bedplates, and fasteners were most susceptible to corrosion due to salt water leakage. To minimize the ship's force burden for equipment preservation, it is recommended that NAVSEA-approved corrosion-control techniques be applied to these affected areas. Wire sprayed aluminum and low- or high-temperature sealer or polyamide epoxy coating (where temperatures permit) are the approved coatings for use on machinery foundations and bedplates, and ceramic-coated fasteners are approved for foundation bolts. Appendix E provides a detailed description of the applicable corrosion-control techniques.

3.3 MAINTENANCE REQUIREMENT IDENTIFICATION

Maintenance data were screened to identify significant maintenance-related problems associated with the low-pressure and the high-pressure compressed air systems. It was found that the low-pressure and the high-pressure air compressors were the high-maintenance-burden equipments in the compressed air system, with system valves and piping contributing to the maintenance burden to a lesser degree.

3.3.1 Ship Service Low-Pressure Air Compressor

3.3.1.1 Description

The Ship Service (Low-Pressure) Air System was initially supplied by four oil-lubricated class S motor-driven air compressors. Ship Alteration LPH-2-0571D installs the oil-free low-pressure air compressor. These new compressors have been installed on all but two LPH-2 Class ships, LPH-2 and LPH-11, which are scheduled to receive them during their next ROH. Since most of the oil-lubricated low-pressure air compressors have already been removed and the remainder are scheduled for removal during the next ROH, this report will not address the older compressors. Performance characteristics of the installed low-pressure air compressors are reflected in Table 3-2.

3.3.1.2 Maintenance History Analysis

Review of the MDS data reported for low-pressure air compressors installed on LPH-2 Class ships revealed a total of 24 maintenance actions that were indicative of major maintenance during the operating cycle (i.e., replacement or repair of internal parts requiring partial or complete disassembly of the compressor). The man-hour burden attributed to these 24 JCNs totaled approximately 1,046 man-days: 47 man-days of ship's force labor and 999 man-days of IMA labor -- corresponding to an average of 2 and 42 man-days per JCN for ship's force and IMA personnel, respectively. It is apparent that the large majority of intracycle repairs are currently being performed by IMA personnel.

The average time between major low-pressure air compressor repairs was calculated by dividing the total LPH-2 Class ship operating years contained within the MDS data period being analyzed (53.13) by the number of major repairs identified (24, from Table 3-3). That calculation reveals that, on the average, one LP air compressor received major repairs every 2.2 ship operating years or, considering the number of ships in the class, every 3.7 calendar months. Since this calculation does not identify particular ships or compressors, its only use is in projecting the total anticipated IMA load for LPH-2 Class low-pressure air compressor repairs over the operating cycle (i.e., an average of one major repair every 3.7 months, requiring an average of 42 IMA man-days for accomplishment).

Review of available SARPs and Historical Repair Profiles indicates that LPH-2 Class low-pressure air system piping and air receivers are generally chemically cleaned and flushed by the depot during regular overhaul. Approximately 69 man-days are typically expended for the chemical cleaning and flushing of the low-pressure air system. Historically, from SARPs, Repair Profiles, Class Maintenance Plans, and MDS data, it was determined that class C repairs of a single low-pressure air compressor during a depot regular overhaul will require approximately 39 man-days and class B overhaul will require approximately 110 man-days.

3.3.1.3 Maintenance Strategy

The results of this analysis have shown that the LP air compressors are redundant in that not all installed compressors are required to operate concurrently to meet 100 percent of the ship's LP air demand. When failures do occur, they tend to be random in terms of the type and timing of the failure. However, the types of failures are normally associated with particular parts (e.g., piston rings, pistons, connecting rods) rather than general equipment deterioration. As a result, class C repairs are normally more appropriate than a class B overhaul. Since ship's force personnel with some IMA assistance are normally capable of making specific repairs of the type previously described and because scheduled maintenance cannot prevent their occurrence, an on-condition maintenance strategy is recommended. The extent of repairs to be accomplished during an ROH should be determined on the basis of operational performance and a pre-overhaul inspection. Class B overhaul should be considered for ROH only when there is clear evidence of need and not on a routine basis. Class C repairs should normally suffice.

3.3.1.4 Recommendations

It is recommended that the following actions be taken with respect to the low-pressure air compressors installed in LPH-2 and LHA-1 Class ships.

- Base low-pressure air compressor repairs (i.e., class C repairs or class B overhauls) during the intracycle period and during regular overhaul upon an on-condition maintenance strategy employing POT&I, MCA, and CSMP as a basis for determining repair requirements.
- Accomplish Shipalt LPH-2-0571D (install oil-free air compressor) on hulls on which it is not already accomplished.
- Chemically clean and flush LP air system piping and air receivers during ROH.

3.3.2 High-Pressure Air Compressor

3.3.2.1 Description

The High Pressure Air System was initially supplied by two oil-lubricated motor-driven air compressors. Ship Alteration LPH-2-0659D installed the oil-free high-pressure air compressor. The new compressors have been installed only on LPH-10. This report addresses the oil-lubricated air compressors only. Performance characteristics of the installed high-pressure air compressors are reflected in Table 3-2.

3.3.2.2 Maintenance History Analysis

Review of the MDS data reported for high-pressure air compressors installed on LPH-2 Class ships identified 14 reported maintenance actions that were indicative of major maintenance during the operating cycle (i.e., replacement or repair of internal parts requiring partial or complete disassembly of the compressor). The man-hour burden attributed to these 14 JCNs totaled approximately 540 man-days (115 man-days of ship's force labor and 425 man-days of IMA labor), corresponding to an average of 8 and 30 man-days per JCN for ship's force and IMA personnel, respectively. It is apparent that the large majority of intracycle repairs are currently being performed by IMA personnel.

The average time between major high-pressure air compressor repairs was calculated by dividing the total LPH-2 Class ship operating years in the MDS data period being analyzed (53.13) by the number of major repairs identified (14) from Table 3-3. That calculation reveals that on the average one HP air compressor receives major repairs every 3.8 ship operating years, or, considering the number of ships in the class, every 6.5 calendar months. Since this calculation does not identify particular ships or compressors, its only use is in projecting the total anticipated IMA load for LPH-2 Class high-pressure air compressor repairs over the operating cycle (i.e., an average of one major repair every 6.5 months requiring an average of 30 IMA man-days).

Historically, from SARPs, repair profiles, Class Maintenance Plans, and MDS data, it was determined that class C repairs of a single HP air compressor by a depot during regular overhaul will require approximately 21 man-days and a class B overhaul will require approximately 138 man-days.

3.3.2.3 Maintenance Strategy

The results of this analysis have shown that the HP air compressors are redundant in that not all installed compressors are required to operate concurrently to meet 100 percent of the ship's HP air demand. When failures do occur, they tend to be random in terms of the type and timing of the failure. However, the types of failures are normally associated with particular parts (e.g., piston rings, pistons, connecting rods) rather than general equipment deterioration. As a result, class C repairs are normally more appropriate than a class B overhaul. Since ship's force personnel, with some IMA assistance, are normally capable of making specific repairs of the type previously discussed and because scheduled maintenance cannot prevent their occurrence, an on-condition maintenance strategy is recommended. The extent of repairs to be accomplished during an ROH should be determined on the basis of operational performance and a pre-overhaul inspection. Class B overhaul should be considered for ROH only when there is clear evidence of need; it should not be performed routinely. Class C repairs should normally suffice.

3.3.2.4 Recommendations

It is recommended that the following actions be taken with respect to the high- and medium-pressure air compressors installed on LPH-2 and LHA-1 Class ships:

- Base high- and medium-pressure air compressor repairs (i.e., class C repairs or class B overhauls) during the intracycle period and during regular overhaul on an on-condition maintenance strategy employing POT&I, MCA, and CSMP as a basis for determining repair requirements.
- Accomplish Shipalt LPH-2-0571D (install oil-free air compressor on hulls on which it is not already accomplished).

3.3.3 Valves and Piping

3.3.3.1 Maintenance History Analysis

Valve repairs as reported in the MDS narratives accounted for 64 significant maintenance actions for the compressed air system APLs. There were 375 IMA man-hours expended on valves, for an average of 6 man-hours per IMA maintenance action; and 303 ship's force man-hours, for an average of 5 man-hours per JCN.

The two principal failure modes were general deterioration and valve leakage. The valves in the compressed air system contributing most of the maintenance burden were determined to be relief valves and reducing valves. Valve malfunctions were corrected by replacement more often than by repair. MDS data showed that the majority of relief valve transactions were for PMS tests that required outside assistance. The MDS data also revealed that IMA personnel perform the majority of valve repairs and replacement, while ship's force man-hours are primarily devoted to routine PMS checks and the ship-to-shop portion of IMA valve repairs. Analysis of past SARPs determined that all compressed air system relief valves are normally overhauled during ROH. No CASREPs were submitted against the compressed air system relief valves during the data period. Considering the number of ships involved, the number of JCNs reported against the compressed air system valves during the data period was small, as was the total man-hour burden devoted to valve repairs. It is therefore concluded that the existing PMS requirements are adequate and no changes should be made.

Review of available SARPs indicated that approximately 200 man-days have traditionally been required during regular overhaul periods for class C repairs of the compressed air systems, including valves, manifolds, filters, reducers, and piping. This man-day estimate includes time normally authorized for hydrostatic testing of the compressed air system. It is further expected that some nonspecific valve repairs will be required during the intracycle period. On the basis of a review of MDS data, it is estimated that ship's force and IMA personnel will expend a total of approximately 85 man-days (38 man-days for ship's force and 47 man-days for IMA) for compressed air system valve and piping repairs every 18 months.

3.3.3.2 Maintenance Strategy

Review of MDS narrative and CASREP data reported against the compressed air system valves indicates that the overall maintenance burden for compressed air system valve and piping repairs is small and that these repairs are not amenable to accomplishment on a scheduled basis. It is therefore concluded that the current on-condition maintenance strategy is appropriate and should be continued.

CHAPTER FOUR

CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

The following conclusions resulted from our analysis of compressed air systems installed on LHA-1 and LPH-2 Class ships:

- An on-condition maintenance strategy should be adopted for the compressed air systems.
- Ship's force and IMAs are capable of overhauling air compressors. Time-directed overhauls of all air compressors during regular overhaul are neither practical nor warranted.
- The compressed air system should be repaired during regular overhaul to the extent shown to be necessary by POT&I results, MCA, and CSMP.
- Failures of the air compressors are generally random, and in most cases ship's force can complete the necessary repairs with limited outside assistance.
- The corrective maintenance history of the compressed air system did not show any failure modes or repetitive maintenance actions indicative of design-related problems.
- With only minor changes the PMS requirements for the compressed air system are adequate.

4.2 RECOMMENDATIONS

Recommendations for scheduled corrective and restorative maintenance actions that are to be accomplished by depots or IMAs are summarized in Table 4-1. It is suggested that these recommended maintenance requirements be incorporated in the LHA-1 Class and LPH-2 Class CMPs. The types of maintenance tasks are as follows:

- E Tasks - Engineered work items that should be carefully considered for accomplishment at the proposed frequency to enable the ship to fulfill its mission. The tasks result from either a long history of experience in system operation or a System Engineering Analysis. The E tasks are generally limited to the ship's critical systems.

- R Tasks - Routine work items accomplished whenever the opportunity is presented (such as drydock work) or for repetitive efforts to support indistrial work such as staging, temporary services, and technical support.
- M Tasks - Mandatory work items accomplished to comply with NAVSEA and Type Commander instructions.
- I Tasks - Inspections performed to comply with NAVSEA or Type Commander instructions.
- T Tasks - Tests or inspections performed during one maintenance availability in order to define maintenance requirements for a subsequent availability. T tasks may also include certain tests and inspections to be performed during the operational period before the beginning of a scheduled maintenance availability.
- Q Tasks - Qualified estimates. These consist of all maintenance actions to be performed on condition; they represent a reservation for manpower and are generally related to the accomplishment of corrective maintenance.

Other improvements to the compressed air system equipments are categorized as follows:

- Design Improvements
  - Recommended shipalts, ordalts, and field changes
  - Recommended equipment redesign or replacement
- Maintenance Strategy Improvements
  - PMS changes
  - Policy
- Support Improvements
  - ILS improvements
  - Maintenance-capability improvements
- Other

These recommended improvements are summarized in Table 4-2.

Table 4-1. RECOMMENDED DEPOT AND IMA CORRECTIVE AND RESTORATIVE ACTIONS

Task Number			Component of System	Quantity per Ship	Task Description	Level of Repair	Repair Estimate	Task Frequency (Months)*	Reference Section
Task Type	SWAB	Number							
M	5511	01	Air compressors	2	Repair, clean, inspect, test, and preserve HP/MP air system separator flask.	Depot	20 man-days	36	3.2.5
M	5511	02	Air compressors	2	Remove, clean, inspect, test, and preserve air flask/accumulator.	Depot	31 man-days	72	3.2.5
Q	5515	01	Air compressors	--	Accomplish class C repairs to H/M air compressors.	IMA/Ship's Force	IMA, 30 man-days; ship's force, 8 man-days	7	3.3.2.2
Q	5515	02	Air compressors	--	Accomplish class C repairs to H/M air compressors as indicated by POT&I results and ship's CSMP.	Depot	21 man-days	ROH	3.3.2.2
Q	5515	03	Air compressors	--	Accomplish class C repairs to (oil-free) low-pressure air compressors.	IMA/Ship's Force	IMA, 42 man-days; ship's force, 2 man-days	4	3.3.1.2
Q	5515	04	Air compressors	--	Accomplish class C repairs to (oil-free) low-pressure air compressors as indicated by POT&I results and ship's CSMP.	Depot	39 man-days	ROH	3.3.1.2
Q	5515	07	Air compressors	--	Accomplish class C repairs to valves, manifolds, filters, reducers, and piping, as required.	IMA/Ship's Force	IMA, 47 man-days; ship's force, 39 man-days	18	3.3.3.1
Q	5515	08	Air compressors	--	Accomplish class C repairs to valves, manifolds, filters, reducers, and piping, as required. Hydrostatic-test system as required.	Depot	200 man-days	ROH	3.3.3.1
E	5513	01	Dry air system	1	Chemically clean and flush the low-pressure air system piping and air receivers.	Depot	69 man-days	ROH	3.3.1.2

*See Section 4.2 for definition of task frequency for specific task type.

Table 4-2. RECOMMENDED IMPROVEMENTS

Component	No.	Recommendation	Reference Section
		Design-ShipAlts	
Low Pressure Air Compressors	1	Accomplish Shipalt LPH-2-0571D (install oil-free air compressor) on hulls that have not already received it.	3.3.1.3
High Pressure Air Compressors	2	Accomplish Shipalt LPH-2-0659D (install oil-free air compressor) on hulls that have not already received it.	3.3.2.3.
		Maintenance Strategy Improvements-PMS Changes	
Low, Medium and High Pressure Air Compressor	3	Use an on-condition maintenance strategy for the air compressors.	3.4
Low Pressure Air System	4	Develop a PMS action to inspect air system for corrosion or damage every 6 months.	3.3.1.3
Air Compressor Foundations	5	Apply wire sprayed aluminum with high- or low-temperature sealer or polyamide epoxy coating, where temperatures permit, on machinery foundations and bedplates, using ceramic-coated fasteners for foundation bolts.	3.2.7
		Support Improvements-ILS Improvements	
		None	
		Other	
	6	A total of 15 significant IMA and ship's force maintenance-related transactions were reported for the compressed air system by the LHA-1 Class ships during the MDS data period -- an insufficient quantity of data for the development of useful results. It is recommended that the general maintenance strategies developed in this report for the LPH-2 Class ships be adopted for the LHA-1 Class ships until sufficient maintenance data are available to determine an appropriate maintenance strategy for the LHA-1 Class ships.	3.2.2

APPENDIX A

SYSTEM BOUNDARIES FOR COMPRESSED AIR SYSTEMS ON LHA-1 AND LHA-2 CLASS SHIPS

This appendix comprises portions of the SWAB description pages excerpted from a copy of ship work authorization boundaries for surface ships, NAVSEA 0909-LP-098-6010, dated March 1981. It defines the boundaries of the compressed air system; it was used as a primary reference source in establishing the system boundaries for this analysis.

The major components subjected to analysis in this report are listed below within their respective SWAB groups:

SWAB 5511

SWLIN 5511X Title: High Pressure Air System

Includes authorized work for:

High pressure air service from outlet valve of compressor to air flasks and from flask to equipment utilizing high-pressure air.

Associated Equipment:

Air flasks	Operating gear
Filters	Piping
Gauges	Regulators
Hangers	Separators
Hose	Valves
Manifolds	

SWAB 5512

SWLIN 5512X Title: Service Air System (MP and LP)

Includes authorized work for:

Medium-pressure (MP), low-pressure (LP) air service from outlet valve of compressor via manifolds and/or regulators to equipment utilizing MP and LP air.

Associated Equipment:

Accumulators	Manifolds
Air flasks	Piping
Dehydrators	Separators
Filters	Strainers
Gauges	Valves
Hangers	
SWAB 5513	

SWAB 5513

SWLIN 5513X Title: Dry Air System

Includes authorized work for:

Ships dry air system that provides clean, oil-free, dry air for radar, automatic combustion control and vital air boiler controls, instruments.

Air sources: high-pressure, medium-pressure, and low-pressure air.

Associated Equipment:

Accumulators	Motor
Air flasks	Operating gear
Dehydrators	Piping
Filters	Purifiers
Foundations	Separators
Gauges	Traps
Hangers	Valves

SWAB 5515

SWLIN 5515X Title: Air Compressors

Includes authorized work for:

High-pressure, low-pressure, medium-pressure, gas turbine air starting, and prairie masker compressors from air intakes to final air discharge, from cooling water inlet flange to cooler inlet flanges, from cooler outlet flanges to cylinder water jacket inlets, from jacket outlets to water outlet flange. Turbine drive -- from steam inlet flange to steam exhaust flange. Electric drive from controller to motor to coupling or pulley.

Associated Equipment:

Air silencer	Controllers
Automatic drain system	Expansion tanks
Belts	Filters
Coolers	Flexible hoses
Coupling	Foundations

Associated Equipment (continued):

Gauges	Separators
Lube oil pumps	Sump
Lube water pumps	Switches
Lubricators	Tachometer
Motors	Thermometers
Mufflers	Unloader
Relief valves	Valves
Resilient mounts	Water flow indicators

APPENDIX B

INSTALLATION CONFIGURATION OF COMPRESSED AIR SYSTEM FOR THE LHA-1 AND LPH-2 CLASS SHIPS

The compressed air systems discussed in this report are composed principally of the components listed in Table B-1. The table provides detailed information regarding the individual component nomenclature, APL number, hull applicability, and number of components installed on each hull. In some instances it appears from the table that particular key components are not installed on some of the ships. In those instances one of the following conditions exists:

- The component has no separate APL.
- The component is not listed in the applicable type commander's COSAL, and no data were reported in MDS or CASREP data for that component.

Table B-1. COMPONENTS OF THE COMPRESSED AIR SYSTEM													
Nomenclature (As listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Compressor Air HIP 20 CFH 3000 PSI CL A	061900145						2		1				
Compressor Air HIP 20 CFH 3000 PSI CL A	061900170							1					
Compressor Air HIP 20 CFH 3000 PSI CL A	061900182										2		
Compressor Air LP 100 CFM 150 PSI CL S	061900194						3					1	
Compressor Air LP 250 CFM 200 PSI CL S	061900206						1						
Compressor Air HIP 20 CFH 3000 PSI CL B	061900224											2	2
Compressor Air LP 100 CFM 150 PSI CL D	061900294											1	
Compressor Air LP 100 CFM 125 PSI CL	061900342									3			
Compressor Air LP 100 CFM 125 PSI CL S	061900359	2	2	2	2	2		5		5			
Compressor Air LP 50 CFM 600 PSI CL T	061900270	2	2	2	2	2							
Compressor Air LP 200 CFM 125 PSI CL S	061900356B	3			3	3							
Compressor Air LP 100 CFM 150 PSI CL S	061900367		3	3	3								
Compressor Air HIP 30 CFM 3000 PSI CL A	061430022									2			
Compressor Air HIP 30 CFM 3000 PSI CL A	061430100							1					
Motor AC 440V 30 HP 1750 RPM	174031476B	2	2	2	2	2							
Controller SZ 440V	151406721B	2	2	2	2	2							
Motor AC 440V 60HP 1740RPM	174031477B	3											
Motor AC 440V 60HP 1800RPM	174753825				[illegible]								
Motor AC 440V 60HP 1770RPM	175504919		3										
Motor AC 440V 60HP 1770 RPM	174031478B			1									
Motor AC 230/460V 5HP 1725RPM	174620425B	3	3	3	3	3							
Controller MAG S24 440V	151406654B	3											
Controller LVP SZ 4 440V	151406734				3								
Controller LVP SZ 4 440V	15180203[illegible]		3										
Controller MAG SZ 4 440V	151407297		2										

(continued)

Nomenclature (As listed on APL)	APL/CID	Quantity by Hull Number											
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Compressor Air LP Refrig. Semi-Hermetic	060250092	3	3	[illegible]	3	[illegible]							
Dehydrator Refrigerant 200 CFM	440210037B	3	3	[illegible]	3	3							
Compressor Air LP RCIPG 100 CFM 125 PSI	061900388												
Motor AC 440V 30HP 1800RPM	174753844		2	2	[illegible]			1					2
Motor AC 440V 30HP 1750 RPM	[illegible]	2								[illegible]			
Controller MAG LVP SZ 3	[illegible]	2		[illegible]		[illegible]				3			
Dehydrator Refrigerant 100 CFM	[illegible]	[illegible]											
Dehydrator Filter Refrigerant D[illegible]	[illegible]		2										
Compressor Air LP Refrig. Semi-Hermetic	[illegible]												
Controller LVP SZ 3 440V	151203125						3						
Controller LVP SZ 3 440V	[illegible]						[illegible]	4	[illegible]	2			
Controller LVP SZ 1 440V	[illegible]						1	[illegible]		4			
Controller LVP SZ 3 440V	[illegible]							2					
Controller LVP SZ 3 440V	[illegible]							[illegible]	1	2	2		
Controller LVP SZ3 440V	[illegible]										[illegible]	2	
Controller LVP SZ3 440V	[illegible]												1
Controller LVP SZ 3 440V	[illegible]											2	[illegible]
Controller LVP SZ 3 440V	[illegible]											2	2
Controller LVP SZ 3 440V	[illegible]								[illegible]		1		
Controller LVP SZ 4 440V	[illegible]								1		1		
Motor AC 440V 50HP 875 RPM	[illegible]								1				
Motor AC 440V 60HP [illegible] RPM	[illegible]												
Motor AC 40 220V 30HP 1800 RPM	[illegible]								1				
Motor AC 40 220V 30HP 1800 RPM	[illegible]										2		
Motor AC 440V 5 HP 3400 RPM	[illegible]							1					

(continued)

Table B-1. (continued)

Nomenclature (As listed on APL)	APL/CID	Quantity by Hull Number													
		LHA					LPH						
		1	2	3	4	5	2	3	7	9	10	11	12
Motor AC 440V 25HP 880 RPM	174751948											2	2
Motor AC 440V 75HP 1775 RPM	174800971									2			
Motor AC 40/220V 75HP 1800 RPM	174620406								4				
Motor AC 440V 75HP 3500 RPM	174180222											2	
Motor AC 440V 30HP 1760 RPM	174750360						3						
Motor AC 440V 30HP 1700 RPM	174750904						3					2	
Motor AC 440V 30HP 1750 RPM	174756633									1			
Dehydrator Filter 30SCFM 100 PSI	440140001									2			
Dehydrator Filter 30 SCFM	440140013						2			2			
Pressure Reducing Station	440200008							4					
Dehydrator Filter RFGT 100 SCFM 100 PSI	440140023											4	3
Pressure Reducing Station TY111	*440200012*						*1*						
Dehydrator Filter DSCC 30SCFM 125 PSI	440210002								1				
Dehydrator Filter DSCC 15 SCFM	440210008												2
Dehydrator Filter RFGT 100 SCFM 150 PSI	440360003							2					
Dehydrator Filter DSCC 30 SCFM 1500 PSI	440210004										2	2	
Dehydrator Filter RFGT 200 SCFM 150 PSI	440210016							1					
Dehydrator Filter DSCC	440200009						2						
Dehydrator Filter DSCC	440190006								1				
Dehydrator Filter DSCC 100 SCFM 100 PSI	440140002										3		
HP Air Filter Int. Dry 3-NB	480020099								1				
Motor AC 440V 100HP 1800 RPM	174752052						1						
Compressor Air LP 100 CFM 150 PSI CL S	061050013								5		5		5
Compressor Air HP 30 CFM 3000 PSI CL A	050250010								1				
Compressor Air LP 70 CFM 200 PSI CL A	061430256											2	

APPENDIX C

APPLICABLE MAINTENANCE INDEX PAGES (MIPs)

The following MIPs are applicable to the major components of the LHA-1 and LPH-2 Class ships compressed air systems:

LHA-1

Component	APL	MIP Number
LP Air Compressor	061900359	A-4/115-31
LP Air Compressor	061900367	A-4/115-31
LP Air Compressor	061900356B	A-4/153-50
MP Air Compressor	061900270	A-36/25-40
LP Air Dryer	440210037B	A-147/30-C9
Electric Air Dryer	440300032	A-147/58-78
LP Air Dryer	440370004	A-147/102-BO
Motors	All APLs	EL-4/28-51

LPH-2

Component	APL	MIP Number
HP Air Compressor	061430100	A-3/22-A5
HP Air Compressor	061900170	A-3/42-70
HP Air Compressor	061900182	A-3/42-70
HP Air Compressor	061900145	A-3/51-36
LP Air Compressor	061900294	A-4/36-11
LP Air Compressor	061900194	A-4/36-11
LP Air Compressor	061900360	A-4/115-31
LP Air Compressor	061900342	A-4/120-89
LP/MP Air Dryer	440200009	A-147/10-97
LP/MP Air Dryer	440210002	A-147/11-58
LP/MP Air Dryer	440200012	A-147/27-82
LP Air Dryer	440140002	A-147/35-B7
LP/MP Air Dryer	440210004	A-147/42-90
LP Air Dryer	440140023	A-147/65-95
Air Dryer	440140013	A-147/69-B5
LP Air Dryer	440360003	A-147/83-90
Motors	All APLs	EL-4/28-51

APPENDIX D

SOURCES OF INFORMATION

The specific sources of information used in this analysis are as follows:

1. Generation IV MDS narrative and part data for the LHA-1 and LPH-2 Classes for the periods May 1976 through June 1981 and January 1971 through March 1981, respectively.

2. CASREPs for the LHA-1 Class for the period 1 January 1976 through 22 April 1981 and for the LPH-2 Class for the period 1 January 1978 through 22 April 1981.

3. Maintenance Index Pages (MIPs) and Maintenance Requirement Cards (MRCs) for the high-pressure, medium-pressure, and low-pressure air compressor systems.

4. Technical Manuals as listed (all NAVSHIPS):

   - 349-0541, *Motor Driven High Pressure Air Compressor,* Worthington Corporation.
   - 349-0761, Volume 1: *Air Purifier-Dehydrator, 30 SCFM, Pressure Reducing Station Panel Type 1, Pressure Reducing Station Panel Type II, and Air Purifier-Dehydrator 250 SCFM.*
   - 349-0473 Instruction Book, *20 Cubic Foot Motor Driven High Pressure Air Compressor,* Ingersoll-Rand.
   - 0949-012-6010, *Medium Pressure Air Compressor Class T Size 50,* Worthington Corporation, Construction Equipment Division, Holyoke, Massachusetts.
   - 348-1561, *Dehydrator-Refrigerant Absorber and Panel Control Air.*
   - *Model ND-1 Dehumidifier, Space Mechanically Refrigerated Self-Contained, 115 Volts, 60 Cycle, 1 Phase AC.*
   - S9514-AW-MMO-010-/MOD 4320, *Operation and Maintenance Instructions: Dehydrator, Low Pressure Air for Special Applications, Type III (Refrigerant-Desiccant), Class 3,* Howell Laboratories, Inc., Model 4320, FSN 9G4130-00-177-8773.

- 0949-LP-060-3010, *Installation, Operation, and Maintenance Instructions, and Parts Information, Low Pressure Air Compressor, 100 C.F.M.-125 P.S.I.*
- 0949-LP-056-6010, *Operation Instructions, Maintenance Instructions, Installation Instructions, Compressor, 125 PSI, 100 SCFM, Oil-Free, General Service Air Model 2JS2B-150.*
- 0949-LP-055-4010, *Installation, Operation, Maintenance, and Repair Instructions with Parts List, High Pressure Air Compressor Model N20NL-2.*
- 0949-LP-055-6010, *Installation, Operation, Maintenance, and Repair Instructions with Parts List, Type III Class 1, Low Pressure Air Dehydrator, Model RD-15 Part No. D26000.*
- 0949-LP-059-4010, *Equipment Manual for Class S 100 CFM-125 PSI Low Pressure Air Compressor.*
- 0949-LP-058-7010, *Operation Instructions, Maintenance Instructions, Repair Instructions with Illustrated Parts Breakdown, Low Pressure Air Dehydrator Type 1, Class 5, NSN 4460-HAO-0206.*
- 0949-LP-058-7011, *Instructions and Parts List, Type 40 Compressor Model 25C, Air Cooled Compressor, FSN 6RX4310-341 4273-SX7X, Part No. Type 40 Model 25C.*
- 0349-047-4000, *Air Compressors Class A and B, Microfilm, No. 1 and No. 2.*
- 0349-051-9001, *Air Compressor (Class A 20 CFH-3000 PSI)* Worthington Corporation, No. 1 and No. 2.
- 0349-047-7000, *Air Compressor, High Pressure,* Bureau of Ships, No. 1 and No. 2.
- 0202-LP-623-3000, *Index of Technical Manuals, USS IWO JIMA (LPH-2).*
- 0904-LP-108-1010, *Technical Manual Index for Amphibious Assault Ship, USS GUADALCANAL (LPH-7).*
- S9LPH-03-ITM-010/LPH-3, *Technical Manual Index, USS OKINAWA (LPH-3).*
- 0905-LP-496-1010, *Operating Guide for Propulsion Machinery, USS OKINAWA (LPH-3).*
- 0905-LP-502-5010, *Operating Guide for Propulsion Machinery, USS IWO JIMA (LPH-2).*
- 0905-LP-485-2010, *Operating Guide for Propulsion and Auxiliary Systems, LHA-1 Class Ship,* Ingalls Shipbuilders, Pascagoula, Mississippi.
- 0905-LP-620-4100, *USS OKINAWA (LPH-3) Ship Information Book, Volume 1, Hull and Mechanical.*
- 0271-LP-033-8000, *USS OKINAWA (LPH-2) Ship Information Book, Volume 1, Hull and Mechanical.*

- (LHA-1) Plan for Maintenance Compressed Air and Gases.
- *DDEOC Class Maintenance Plan (CMP) Comparison (FF-1052, DDG-37, CG-16 and CG-26 Class Ships) Study for PERA (CRUDES)*, dated September 1980.
- Results of ARINC Research Corporation visit to David Taylor Naval Research and Development Center, dated 12 May 1982.

5. Ship Alteration and Repair Packages (SARPs)

- LPH-2, dated 6/8/82
- LPH-3, dated 3/11/82
- LPH-7, dated 10/31/80
- LPH-9, dated 8/18/80
- LPH-10, dated 1/9/81
- LPH-11, dated 10/23/81
- LPH-12, dated 5/15/81
- LHA-1, dated FY 78 RAV
- LHA-2, dated 6/13/82 (COH)
- LHA-1, dated FY 81 (COH)
- LHA-3, dated 1/15/82 SRA
- LHA-2, dated 7/3/81 SRA

6. Ship Alteration Information Manuals for LHA-1 and LPH-2 Classes of ships.

7. COMNAVSURFLANT and COMNAVSURFPAC Type Commanders' Coordinated Shipboard Allowance Lists (COSALs), dated July 1981 and June 1981, respectively.

8. COMNAVSURFLANTINST 9000.1, *NAVSURFLANT Maintenance Manual*, 12 June 1975, through change 5, dated 27 February 1978.

9. COMNAVSURFLANTINST 4700.1, *COMNAVSURFPAC Ship and Craft Material Maintenance Manual*, Volume I, 6 June 1975.

10. *FF-1052 Class High Pressure Air System Review of Experience*, SMA 208-551-2, July 1977, ARINC Research Publication 1646-03-16-1630.

11. *DDG-37 Class Compressed Air Systems Review of Experience*, SMA 37-204-551, June 1978, ARINC Research Publication 1652-03-18-1763.

12. *CG-16 and CG-26 Class Auxiliary Systems Review of Experience*, SMA 1626-500, September 1979, ARINC Research Publication 1671-04-2-2051.

13. OPNAVINST 4790.4, *Material Maintenance Management (3-M) Manual*, Volumes I, II and III, June 1973.

14. Common Configuration Class List (CCCL) for LHA-1 and LPH-2.

15. Ship Work Authorization Boundaries (SWABs), Surface Ships, March 1981.

16. Results of ARINC Research Corporation visits to LPH-7 and LPH-12 on 20-21 April 1982.

17. Class Maintenance Plans (CMPs) for FF-1052 Class, DDG-37 Class, CG-16 and CG-26, LHA-1 Class ships.

18. Results of ARINC Research Corporation visit to LHA-2 on 4 June 1982.

19. Results of ARINC Research Corporation telephone consultation with Charleston Naval Shipyard lube oil analysis laboratory personnel on 28 June 1982.

APPENDIX E

CORROSION-CONTROL TECHNIQUES

Table E-1 presents recommended work (SARP) statements for applying the NAVSEA-approved corrosion-control systems. Table E-2 presents specific guidance for applying the corrosion-control systems to common components within the compressed air system.

Table E-1. RECOMMENDED CORROSION-CONTROL SARP STATEMENTS			
SWAB	Problem Area/ Components	Recommended SARP Statement	Alternate Corrosion-Control System(s)
5512	Air system, low and medium pressure	When LP air piping, steel valves, valve manifolds, and hangers are over-hauled or replaced, apply WSA with low-temperature sealer. Use fasteners treated with ceramic coatings or use improved fasteners as applicable. Guidance item 2 applies to piping, hangers, and fasteners. Guidance item 3 applies to valves.	Apply polyamide epoxy paint. Apply strip-pable coatings to fasteners.
5515	Compressors, air	When air compressors are removed from the ship for overhaul or replacement, apply WSA with low-temperature sealer to compressor foundations and casings. Apply poly-sulfide sealant to faying surfaces. Use fasteners treated with ceramic coatings or use improved fasteners as appli-cable. Guidance item 1 applies to machinery foundations, bedplates, and fasteners.	Apply polyamide epoxy paint. Apply strip-pable coatings to fasteners.

Table E-2. CORROSION-CONTROL GUIDANCE ITEMS		
Item Number	Equipment	Guidance
1	Machinery Foundations and Bedplates	When a new foundation or bedplate is installed or a bedplate is removed as part of machinery overhaul, or a foundation is located topside, abrasive-blast the foundation and mating structure surface to white metal (SSPC-SP5), and then apply 7-10 mils of WSA low-temperature sealer (MIL-P-23377) and two-coat polyamide epoxy (MIL-P-24441) system. For machinery foundations and bedplates located in machinery spaces and subjected to temperatures above 175°F, use WSA with high-temperature sealer (DOD-P-24555). Use fasteners treated with ceramic coatings or use improved fasteners.
2	Piping and Hangers	In areas exposed to the weather and in machinery spaces (where piping is replaced) abrasive-blast ferrous piping and pipe hangers/brackets to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature), and polyamide epoxy coating (MIL-P-24441). If piping is not replaced, apply three-coat polyamide epoxy system (MIL-P-24441). Treat fasteners with ceramic coating (MIL-C-81751) or use CRES fasteners.
3	Valves	Abrasive-blast valve exterior to white metal (SSPC-SP5) and apply 7-10 mils of WSA, low- or high-temperature sealer (depending on operating temperature of fluid or if steam valve), and polyamide epoxy coating (MIL-P-24441). Technical Manual NAVSEA S6435-AE-MMA-010/W, *Sprayed CTT, External Preservation of Steam Valves Using Wire Sprayed Aluminum Coatings*, provides detailed guidance. Upgrade/treat fasteners with ceramic coating (MIL-C-81751) or replace with CRES fasteners and apply polysulfide sealant (MIL-S-81733).

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